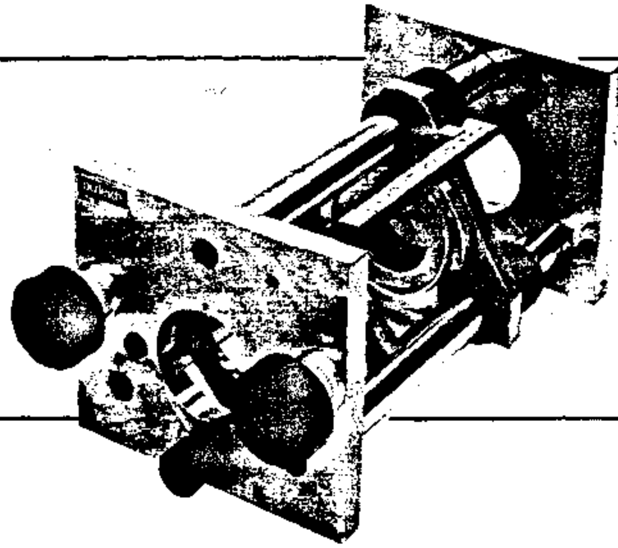

Fabry–Perot Instruction Manual

burleigh

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1. INCOMING INSPECTION

A. Visual Inspection of Shipping Container

The Burleigh RC Series Fabry-Perots, Ramp Generator and RC Series Mirrors are packed in specially designed containers according to sound packaging principals to prevent damage during shipment. On arrival, inspect the package carefully for any evidence of handling abuse. If any is found, contact your purchasing and/or shipping departments immediately. Instruct these departments to inform the shipper or his agent that damage to the shipping container has been found. The shipper may wish to inspect the package before opening.

B. Visual Inspection of the Equipment

Unwrap or unpack each of the packages carefully. CAUTION: Do not throw away any paper or packing material without first determining that nothing is enclosed. Do not discard the shipping container until it has been established that there is no damage to the equipment. You may also want to retain this container for storage or transportation of the instrument.

Visually examine each item to be sure everything is included and identified on the packing slip. Consult Section 2 for descriptions.

Next, gently shake the instruments. If a rattle is apparent damage during shipment may have occurred. Again, notify Burleigh and the shipper through the appropriate channels. If you determine that an item has been omitted from your order, recheck the shipping container. If nothing is found, please call Burleigh for possible corrective action.

C. Performance Inspection

A word about Burleigh's Quality Control. Every effort is extended to insure that the instrument shipped to you works according to specification. It is very expensive to have a defective instrument returned to the factory and to have an unhappy customer.

As an example of Burleigh's Quality Control, your unit has undergone numerous visual inspections, individual testing of active parts and extensive long term testing of the complete assembly. However, with sophisticated instruments, very small or subtle shipping damage may occur which could seriously affect performance. In view of this, please inspect the instruments as soon as possible after receipt so any problem can be promptly identified and corrected.

D. General Comments

Each unit shipped is assigned a Burleigh serial number. Please refer to this number during any phone conversation or written communications.

Do not return your unit to Burleigh without obtaining a return authorization number. Unauthorized shipping can void any claim you or Burleigh may have against the shipper or his agent.

2. INSTRUMENT DESCRIPTION

A. Design Considerations for Burleigh's RC-110, RC-170, RC-140 or RC-150.

1) Mechanical Design

The RC Series Fabry-Perots are designed with particular emphasis on freedom from angular and axial cavity drift with time and temperature. See Figure 1. The mainframe is designed with three-fold rotational symmetry (the symmetry of an equilateral triangle) about the axis normal to the mirror plane. This necessitates that the PZT drive elements and Super-Invar rods be located at 120°. This design approach helps assure the maintenance of mirror parallelism over long periods of time. The Super-Invar adjustment screws are located at 90° for orthogonal adjustment, but vertical symmetry is still maintained.

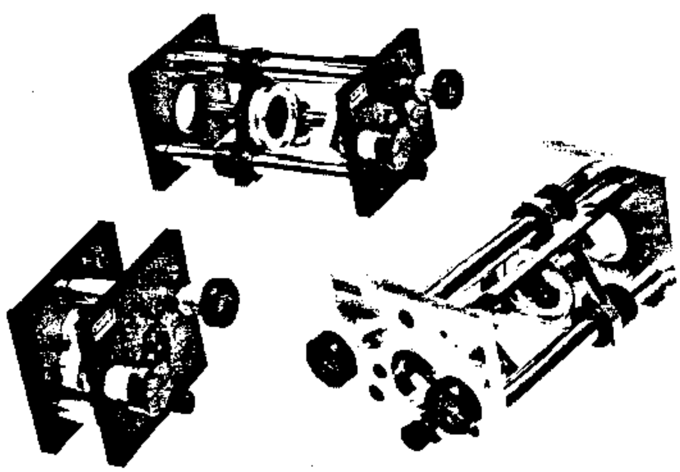


Figure 1. RC Series Fabry-Perots. RC-170 not Shown

2) Choice of Materials

Each of our Fabry-Perots use Super-Invar, Invar, low thermal expansion ceramic insulators and low thermal expansion PZT material in a reentrant design to control the spacing of the mirrors in the Fabry-Perot cavity. Every mechanical part directly affecting the thermal stability of the RC-110 (-170, -140, -150) is machined of Super-Invar ($\alpha \leq 0.36 \times 10^{-6}/^{\circ}C$) or Invar ($\alpha$ $1.6 \times 10^{-6}/^{\circ}C$). This includes sleeves, drive plates, mirror holders, adjustment screws and rods. In fact, because the design is reentrant there may be zero axial drift at some cavity spacing. Also, by judicious placement of thin metal washers, it is sometimes possible to make the axial drift zero at a selected cavity spacing. For optimum performance the environment should be thermally very uniform and slowly changing.

The RC-110 and RC-170 are made almost completely of Super-Invar. The use of similar materials throughout, added to the extremely low thermal expansion of the Super-Invar, means optimum thermal stability. The added mass of the Super-Invar also helps insure mechanical stability.

The RC-140 and RC-150 use Super-Invar and regular invar for mechanical parts directly affecting the cavity spacing. Aluminum is used elsewhere. Aluminum is a proper choice because of its excellent thermal diffusivity. Thermal gradients are rapidly diffused throughout the instrument body to inhibit misalignment found in interferometers using iron or other similar materials. Since the aluminum is not used where it can influence the cavity spacing, thermal performance is maintained.

3) PZT Material

All Burleigh Fabry-Perot Interferometers use matched sets of PZT elements to provide electrical parallelism adjustment of the interferometer cavity as well as electrical scanning over its free spectral range. The PZT elements are constructed from interferometrically matched PZT discs. The PZT material used for scanning offers the best linearity and hysteresis characteristics; less than 1% inter-order linearity and 1/2% hysteresis. With the Programmable Ramp feature of Burleigh electronics the scan linearity can be reduced to $\leq 0.1\%$. A high sensitivity material is used for a large alignment range.

There are three reasons PZT discs are used instead of PZT cylinders. The first is discs have a lower coefficient of thermal expansion than cylinders. This greatly improves the thermal stability of the Fabry-Perot. The second reason is discs have a higher "d", or piezoelectric coefficient, than PZT cylinders. This allows a shorter PZT drive, further improving thermal stability. The compactness also minimizes cantilevering of the drive mirror and strengthens the assembly. The third reason is that discs ensure a more rigid mechanical construction. Discs have a larger surface area in the direction of expansion and more closely approach a solid member. Disc assemblies are therefore less prone to resonances when driven at high frequency.

4) Adjustment Screws

The all Super-Invar adjustment screws used in the Fabry-Perots have very high resolution capability with greater than 10mm adjustment range. This is necessary for precisely setting the mirror spacing and alignment for final mechanical alignment of the mirror cavity.

The adjustment screw assembly uses 250μm/turn metric threads with 5cm diameter Delrin knobs for improved resolution and metric readout. Adjustments to 1/10μm are easily made. With the scale and dial, the screw position can be read to 5μm and interpolated if necessary.

There are two other advantages to the Super-Invar screws which are not realized with other types of screws. One advantage is the inherently reduced sensitivity of the interferometer cavity to thermal perturbations. Beside the advantages of the Super-Invar with its lower absolute thermal expansion, there is the advantage offered by using metal from the same batch to make each set of screws. Different batches of the same metal can have varying coefficients of thermal expansion, a serious problem in screws made with high-expansion materials. These differences are less important in the Burleigh screws because they are made of Super-Invar instead of some other material with a larger thermal expansion.

The second advantage is that the thread engagement of each of the screws is always closely matched. For instruments using a differential screw adjustment, it may be necessary to make significant adjustments to the differential screws in the process of mechanically aligning the mirrors. The threads will not be engaged identically for all three differential screws, meaning expansion of each screw shaft is controlled from a different point. This can introduce angular drift in the instrument due to temperature changes. This problem can be significant in steel differential screws.

5) Assembly

All Burleigh interferometers are designed with hard connections between mechanical and piezoelectric parts. There are no soft plastic materials, compliant joints or RTV-like substances to creep and move: these are major causes of misalignment and drift problems in Fabry-Perots.

6) Model RC-110 and RC-170 Fabry-Perots

The RC-110 and RC-170 are general purpose, scanning Fabry-Perot interferometers with superior thermal and mechanical stability. They are constructed almost completely of Super-Invar. The end plates, rods, sleeves, mirror mounts, and even the adjustment screws are Super-Invar. The thermal expansion of Super-Invar is $\leq 0.36 \times 10^{-6}/^{\circ}C$, about 5 times lower than regular invar ($\alpha \sim 1.6 \times 10^{-6}/^{\circ}C$). For comparison, stainless steel has an $\alpha = 9.6 \times 10^{-6}/^{\circ}C$ and brass has an $\alpha = 11.4 \times 10^{-6}/^{\circ}C$. Low thermal expansion means stability is maximized.

The RC-110 and RC-170 are piezoelectrically scanned using three PZT elements operated in parallel and made from Burleigh's low hysteresis, low expansion, high linearity PZT material. The PZT stacks are interferometrically measured and matched for tilt-free scanning. Alignment is accomplished with three high sensitivity elements for a large adjustment range.

The mirror spacing of the RC-110 is continuously variable from 0 to 150mm and the RC-170 from 0 to 110mm. This allows an optimum compromise between free spectral range and resolution. Split tube clamps lock the moveable mirror support plate firmly in place after the gross cavity spacing is set. The split tube clamps are precision honed Super-Invar sleeves. These sleeves have a 1.5:1 length to diameter ratio to allow the spider to slide smoothly along the precision ground Super-Invar rods without marring or binding. The RC-110 provides up to a 50.8mm clear aperture and is compatible with standard Burleigh Mirror Sets which allow a maximum 50.8mm clear aperture (flatness guaranteed over 80% of the aperture). The RC-170 has a 70mm aperture and accepts RC-690 Mirror Sets (flatness guaranteed over 80% of the aperture).

There are a number of convenience features too. For instance, the cavity length scale reads to 0.1mm. The Super-Invar adjustment screws let you precisely change the cavity spacing by less than 1μm. The screws are metric. And the convenient dial can be read to 5μm. The exposed Super-Invar parts of the RC-110 are chrome plated.

The PZT drives are constructed of laminated PZT discs connected electrically in parallel. A thin wafer of rigid, low thermal expansion Alumino-Silicate ceramic is laminated to each end of the stack to provide electrical isolation. The PZT stack assemblies are bonded between Invar plates to form an integral PZT drive assembly. Aluminum shields prevent accidental touching of the PZT stacks which have up to 1000v applied. This construction technique produces a thermally compensated assembly of minimum length, maximum sensitivity and rigidity. It also allows easy interchangeability between PZT assemblies.

7) Model RC-140 Fabry-Perot

The mechanical configuration of the RC-140 is identical to the RC-110. The only difference is the materials used in the construction. The end plates and spider are made of aluminum instead of Super-Invar. Care is taken to define thermal expansion reference planes wherever Super-Invar parts are attached to the aluminum support members. This insures that the expansion of the aluminum does not affect stability. Aluminum has good thermal diffusivity to minimize the effects of thermal gradients.

8) Model RC-150 Fabry-Perot

The model RC-150 is especially designed for those who do not need large cavity separations. The RC-150 is similar to the RC-140 in mechanical construction. The difference is in the cavity separation scheme employed. The RC-150 uses Super-Invar spacers to determine the cavity spacing instead of continuously varying the spacing by sliding one mirror mount relative to the other. The gross cavity separation of the RC-150 can be changed discretely using the optional Super-Invar spacers. The optional spacer set permits cavity spacings from 1 to 5cm in increments of 1cm. For cavity separations between the fixed values above, the fixed mirror mount can be translated ± 0.5cm by adjusting the three adjustment screws.

B. Mirror Holders

Two of the most important considerations in Fabry-Perot Interferometry are the mechanical rigidity and thermal stability in the mounting of λ/200 plates or mirrors. Mounting must be accomplished without stressing or distorting the mirrors. With Burleigh's mounting method, three Invar tabs are epoxied to the edge of each mirror. These tabs have glass spheres secured into holes bored into each tab. The mirror, with tabs, is then placed into an invar holder with three small hardened V-groove pads at 120°. The glass spheres sit in these grooves, and a spring load is applied to the top of the glass spheres to hold them firmly against the grooved pads. Thus the mirror position is well defined mechanically and thermally with no forces which can stress or distort the mirrors. See Figures 2 and 3. All RC Series Mirror Sets are mounted with this technique.

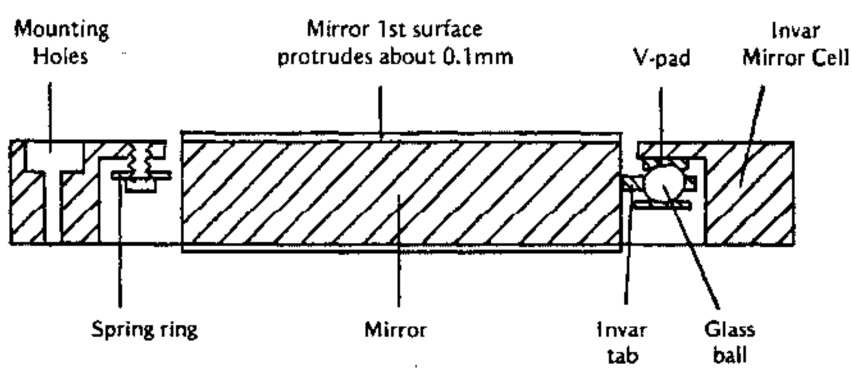


Figure 2

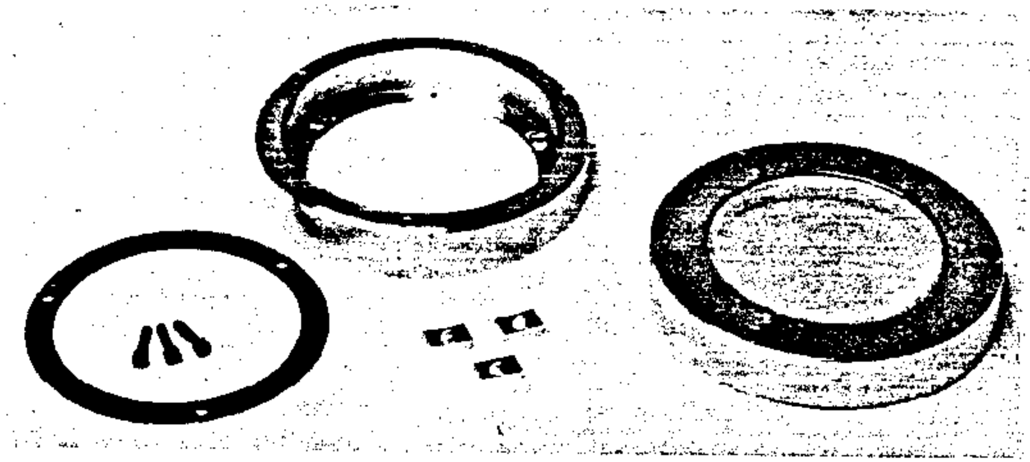


Figure 3. Burleigh Fabry-Perot Plate Mounting Technique

Each mounted mirror is then secured in the interferometer with three screws. The advantages of this method are: the mirror surface is precisely referenced to the invar ring, such that when the invar rings of both mirrors of the cavity touch, the mirrors can protrude slightly from their holders to allow for very small mirror spacings. The method results in a design which is well constrained for rigidity and does not distort the mirror surfaces.

C. Ramp Generators

The Burleigh RC-43 or RC-44 Programmable Ramp Generators are designed to operate with the RC-110, RC-170, RC-140 or RC-150 Fabry-Perots. Consult the separate instruction manual for operation.

D. DAS Stabilization Systems

DAS-1 and DAS-10 Data Acquisition/Stabilization Systems authomatically correct for cavity drift and misalignment of the Fabry-Perot. Refer to the Fabry-Perot catalog for further detail.

E. Collimator and Mounting Brackets

Some imaging system must be used to collect the light at a pinhole. The RC-41 Collimator uses a 48mm aperture achromatic lens of a nominal 250mm focal length and a set of x-y positionable pinholes for this purpose. Interchangeable pinholes of 50, 100, 200, 500μm are easily screwed into the x,y slide. Two micrometer heads provide precise adjustment of the pinhole location at the focal point of the lens. The pinholes are precision laser-drilled and mounted in holders.

All elements of the collimator are mounted in one tube. The RC-41-1 Mounting Bracket is recommended. This bracket positions the collimator at the correct optical axis height for the RC-110, RC-170, RC-140 or RC-150.

F. Thermatrol and Thermal Box

The RC-75 Thermatrol^{tm} is an insulated, temperature controlled enclosure for all Fabry-Perots. It maintains the temperature to $\leq 0.05^{\circ}C$. The RC-34 Thermal Box is a passive enclosure; it is an RC-75 without temperature control and has ½" polyurethane insulation inside a walnut stained box. The windows are removable.

G. Composite Kinematic Mounting Base

The RC-24 Composite Kinematic Mounting base provides θ, ϕ and ψ angular adjustment as well as vertical positioning for all Fabry-Perots. Super-Invar is used to reference the end plates and the positioning is kinematic for stress-free mounting and precise repositioning on the optical axis. The RC-24 can be ordered mounted in the RC-34 or the RC-75 or it can be used freestanding.

II. Multipass Options

The RC-22 Multipass Option allows 3-pass or 5-pass operation of the RC-110 or RC-140 Fabry-Perots with any Mirror Set. The apertures in 3 or 5 pass are 11mm or 5mm respectively. The RC-27 allows 3-pass or 5-pass operation of the RC-170 with a RC-690 Mirror Set and provides apertures of 15mm or 9mm respectively. Consult the Fabry-Perot catalog and the Multipass Option Tech Memo for more detail.

3. OPERATION

A. RC-110, RC-170 or RC-140 Fabry-Perot

To set up the RC-110, RC-170 or RC-140 for operation, consult Figure 4a, Figure 4b and the following directions:

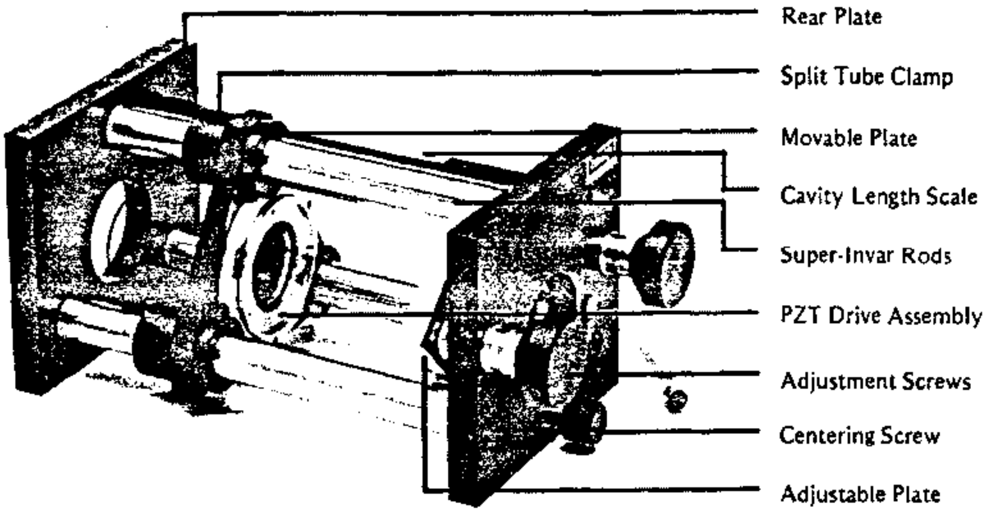


Figure 4a. RC-140 Fabry-Perot. RC-110 similar but constructed entirely of Super-Invar

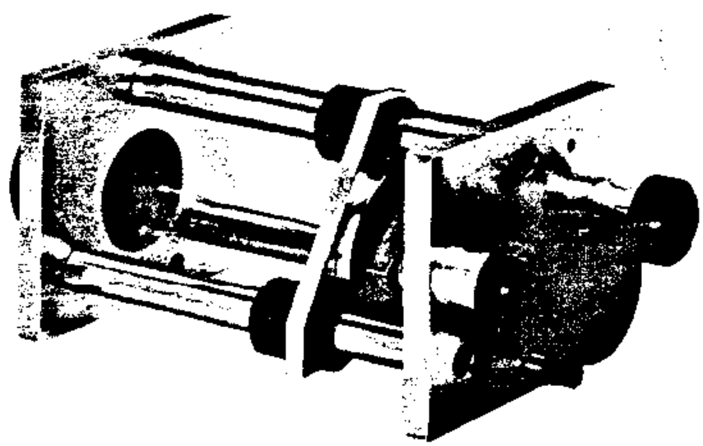


Figure 4b. RC-170 with RC-27 Multipass Option

(1) Carefully remove the cardboard and tape around the plate controlled by the screws. Note that this screw plate is held off the end plate by three screws. Carefully extend the adjustment screws until they seat in the sapphire V-blocks and move the screw plate off the end plate. Now the three screws in the screw plate can be removed. The cavity spacing is read with the cavity scale. There is no direct correlation to scales and dials on the adjustment screws, although they can be used if they are calibrated. The scale is zeroed at the factory for a typical set of mirror holders. Standard factory setting allows the cavity to be read to an accuracy of 0.1mm due to machining tolerances and mounting errors. If a spacing accuracy of greater than about 0.1mm is required, the adjustment screw scales and dials should be calibrated with the mirrors in place. The scale can then be read to 5μm

(2) Loosen the three split tube clamps on the moveable support plate that rides along the three Super-Invar rods. Slide the moveable support plate to the end opposite the other mirror mount. Tighten the clamps. Stand the instrument on each end and insert the RC-600 Series mirrors into your Fabry-Perot with the screws provided. The mirrors are mounted in special Invar holders. The Fabry-Perot plates have a wedge angle of 10-15 arc-min. The point of maximum thickness is marked by an arrow scribed onto the edge of each plate (note: this arrow also points to the first surface). The plates should be mounted in the Fabry-Perot such that the arrows on each plate are 180° apart in order to minimize angular beam deviation through the Fabry-Perot. Be careful not to pinch the cable. Also when placing the Fabry-Perot on end make sure the micrometers do not damage the sapphire V-blocks.

(3) Set the desired mirror spacing. The mirror spacing is given by: the 0-150mm scale reading minus the 0-10mm reading on the large knobs. The accuracy is about 0.1mm; for a more accurate indication the spacing must be accurately measured for each mirror set.

(4) The RC-41 Collimator can be attached to the RC-41-1 Mounting Brackets.

(5) Connect the 10 foot cable to the Ramp Generator or DAS. The connector contains seven leads for bias, ramp functions and ground.

B. RC-150 Fabry-Perot

In general, operation of the RC-150 is the same as the operation of the RC-140, with the following exceptions. See Figure 5.

Gross cavity separation is governed by Super-Invar spacers. These spacers are of specified lengths in 10mm increments. The RC-150 does not have a cavity scale so the spacing must be measured. The adjustment screws can be calibrated and used to set and read the cavity spacing to 5μm within their 10mm range.

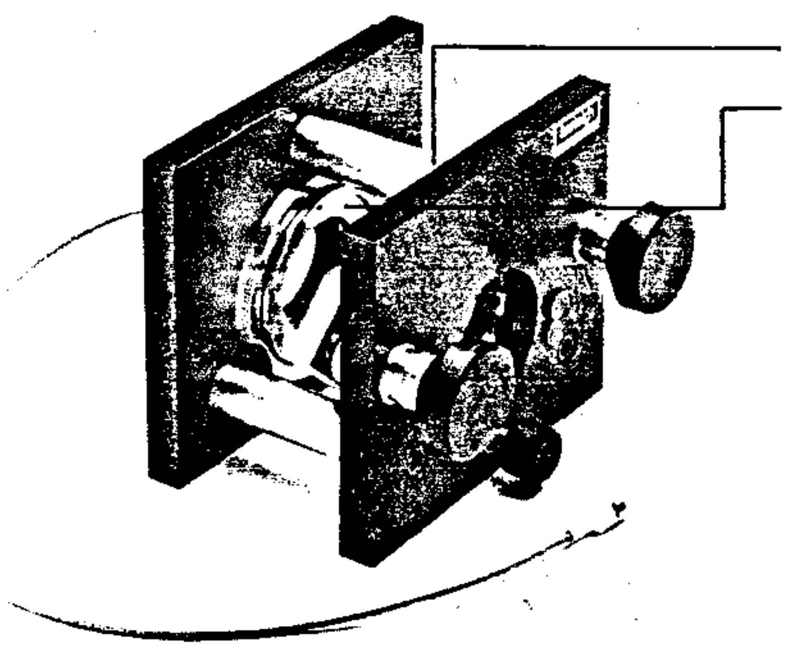


Figure 5. RC-150 Fabry-Perot

C. General

The PZT stacks have Alumino-Silicate end insulators and are epoxied to the plates of the PZT drive assembly. This package is attached to the Fabry-Perot with three screws. It is easily removed or changed, if an infrared PZT drive is required, for example.

4. SET-UP AND ALIGNMENT IN THE VISIBLE, UV AND NEAR IR

A. Preliminary Discussion

Aligning of the interferometer is most easily accomplished by using a small cw laser (e.g. He-Ne laser) as the source. Although such a source is not absolutely necessary for small plate separations, it becomes increasingly vital for rapid and easy adjustment as the plate separation becomes large (d=1cm). It is not necessary that the laser wavelength correspond to the reflectivity peak of the mirror coatings; even 20% reflectivity at the laser wavelength is adequate. Mirrors for the visible, UV and near IR can normally be aligned with this technique if the substrates are transparent to the gas laser wavelength. Alignment consists of two major operations:

1) Making the mirrors parallel.
2) Making the pinhole of the collimator coincident with the central spot of the Fabry-Perot fringe pattern.

The formal operation usually proceeds in three steps:

1) An initial rough adjustment using the adjusting screws.
2) A fine adjustment using the adjustment screws.
3) A super-fine adjust using the PZT stacks. For convenience, the mirror adjusted by the adjustment screws shall be referred to as A, and the mirror adjusted by the PZT drive assembly as B.

At this point connect the Ramp Generator as described in its operating manual. Bias controls should be set to mid-position. The ramp should be turned off and each pot in the Slope Trim Section turned fully counterclockwise. The power light should be on.

B. Rough Adjustment

First, it is necessary to make the laser beam perpendicular to the mirror B, as shown in Figure 6. The laser should be sent through a hole in a card approximately 1mm in diameter. By adjusting the angular position of the laser or the interferometer, the beam reflected from B can be made to pass directly back through the hole.

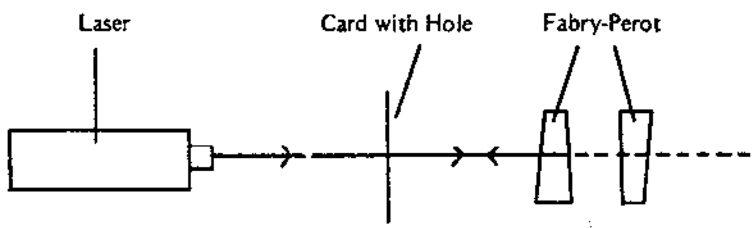


Figure 6. Alignment of Fabry-Perot Perpendicular to Beam

The transmitted beams are now viewed on a distant screen, as shown in Figure 7. By adjusting the angular tilt of A with the adjustment screws, the spots on the screen may be made coincident. This completes the rough adjustment.

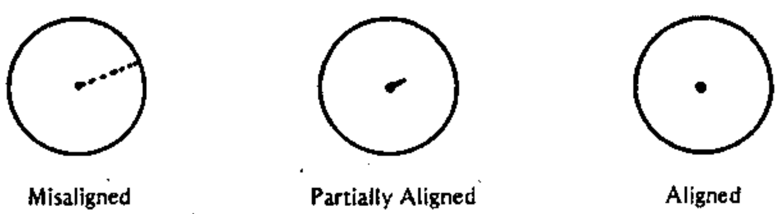


Figure 7. Alignment with Small Diameter Visible Laser Beam

C. Fine Adjustment

At this point two techniques can be used.

If the Fabry-Perot is illuminated with a large, collimated laser beam, several straight line fringes will be observed on a white card at the output. See Figure 8. The plate separation increases by $\lambda/2$ for each fringe observed. Thus if six fringes are observed, the plates will be tilted by $6 \times \lambda/2 = 3\lambda$ across the diameter of the beam. Using the adjustment screws and PZT's if desired, the plate alignment can be improved until there are no fringes in the field. Perfect alignment will result when the cavity is tuned with the PZT's to transmit the source wavelength and the observed light field is symmetrically illuminated. See Figure 9. If a collimated source is not available, the laser beam can be used. Rearrange the light source, as shown in Figure 10. Diverge the laser on to a white card with a spot size approximately equal to the plate diameter. It should now be possible to see fringes by looking in at the B mirror side, again as shown in Figure 9. Since the pupil of the eye is only a few mm in diameter, it sees only "local" fringes generated by a corresponding small cross section of the mirrors. By moving the head up and down or sideways, the fringes will be seen to expand or contract, unless the mirrors are already aligned perfectly. An opening up of the rings means that the plate separation is increasing, and a closing down means that the separation is decreasing.
If the central fringe is almost collapsed, this technique is extremely sensitive. Thus one can tell immediately which way the mirrors must be tilted about an axis perpendicular to the head movement in order to improve mirror parallelism. By adjusting each of the two orthogonal adjustment screws, and by repeating the sequence several times, the mirrors can be brought into nearly perfect parallelism very rapidly. The operation will proceed most rapidly if the head motion is always perpendicular to the two orthogonal axes about which the adjustment screw in question rotates the mirror.

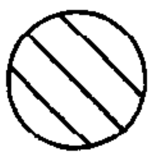


Figure 8. Alignment with Large Collimated Beam. Misaligned by Three Fringes

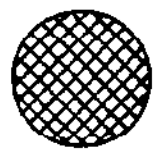


Figure 9. Alignment with Large Collimated Beam. Perfect Alignment with Fabry-Perot Tuned to Input Wavelength

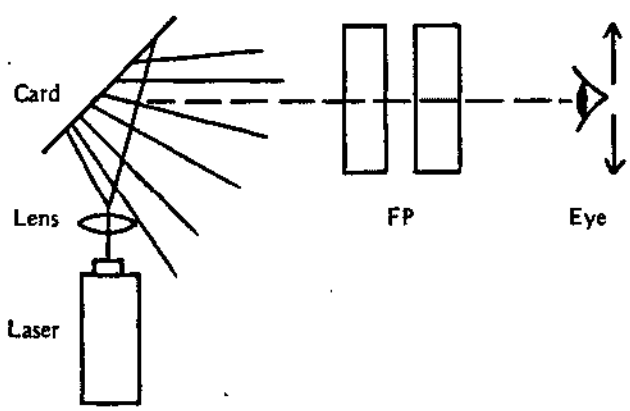


Figure 10. Viewing Fabry-Perot Circular Fringes with Eye

D. Super-fine Adjustment

Upon completion of alignment with the adjustment screws, final parallelism adjustment may be made with the bias controls using the method of section 4C to check parallelism. If for optimal alignment one of the bias controls is near the end of its scale, it is a good idea to adjust the corresponding adjustment screw, so that all bias controls are returned to approximately mid-scale. This will allow for maximum flexibility in making future electrical adjustments.

E. Survey of Mirror Flatness

After the adjustments of sections 4C and 4D have been carried as far as possible, it may be noted that the ring diameter cannot be kept constant over the whole surface of the plates. That is, unless the mirror flatness is perfect, one can usually find mutually "high" or "low" spots on the mirrors. When the central ring is nearly collapsed, the ring diameter will be extremely sensitive to plate errors since the ring diameter is a cosine function. If such deviations seem excessive, they are probably due to one of the following causes:

1) The mirrors may not have been properly mounted, i.e., the mounting has induced strain in the mirror blank.

2) The mirror blanks may not be up to specification.

3) The coating may not be as flat as the substrate.

4) The coating may have stressed the substrate.

One can often improve the finesse of an instrument by using a smaller aperture to limit the incoming beam to the best section of the mirror. Burleigh Fabry-Perot plates normally have a slight spherical deviation from perfect flatness. Burleigh tests all mirror sets for flatness before shipping.

F. Adjustment of the Collimator

The focus of the collimator lens must first be adjusted. This is accomplished before the collimator is attached to its base. Screw the pinhole device containing the eyepiece lens into the X-Y slide. Note that this device contains a rather large hole approximately 3mm in diameter in lieu of an actual pinhole. Adjust the eyepiece lens until the edge of this hole is seen clearly in sharp focus. The edge of the hole is in exactly the same position along the axis of the objective lens as that of the actual pinholes. Now look at a very distant object through an open window, and adjust the collimator objective lens until the image of the distant object seems to be suspended in space at the plane of the hole. Focusing is now complete, and the collimator may be attached to its base.

With the Fabry-Perot illuminated as in Figure 11, view the ring pattern through the eyepiece lens of the collimator. Adjust the lateral position of the eyepiece with the two micrometer screws, such that the ring pattern is exactly concentric with the large hole. The eyepiece may now be unscrewed and replaced with the working pinhole. The pinholes have been accurately machined so that they will be close to the exact center of the large hole on the x-y slide. Thus, the working pinhole will now be within about 25μm of the correct position.

USE CAUTION WHEN VIEWING THE BEAM TO AVOID EYE DAMAGE; THE INTENSITY OF THE BEAM SHOULD BE ATTENUATED AS MUCH AS POSSIBLE.

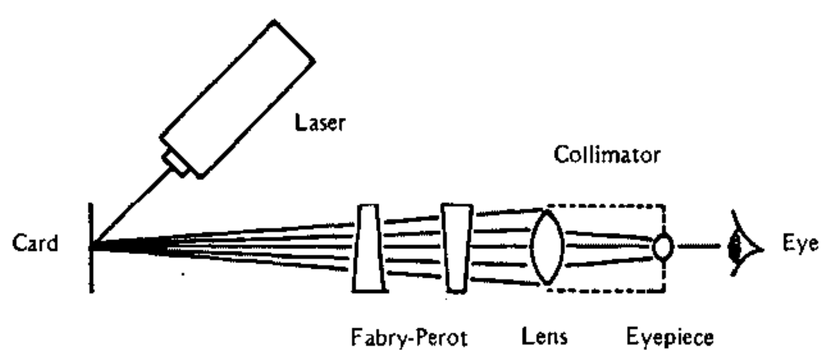


Figure 11. Viewing Fabry-Perot Circular Fringes through Collimator

G. Final Adjustment

1) Finesse

As a check on the overall alignment of the Fabry-Perot, and to make any final touch-up adjustments that may be necessary, one should observe instrument finesse in the electronically scanned mode. That is, with a photomultiplier or photodiode located behind the pinhole, the output of the detector should be connected to the vertical amplifier of a scope. The horizontal amplifier should be driven with either the output ÷ 100 from the Ramp Generator or the time base of the scope by triggering it with the trigger output of the Ramp Generator. The spectrum of a cw laser should then appear as a series of sharp peaks on the screen. See Figure 12. (A scan time of 50ms to 100ms provides a nearly flicker free presentation on the scope screen that is easy to view).

Small pinholes can be precisely centered on the fringe pattern by adjusting each micrometer screw on the x-y pinhole slide such that the fringes move in one direction (e.g. always to the left) as a micrometer is advanced or retracted from the center of the fringe pattern. See Figure 13.

Also it may be possible to sharpen up a laser line by making slight adjustments of the transducer bias controls. The optimum mirror parallelism can be achieved this way.

2) Slope Trim

In a Fabry-Perot Interferometer, if the three piezoelectric scanning elements have slightly different sensitivities tilting during scanning will result. The amplitude of the fringe pattern in each free spectral range will change as the Fabry-Perot scans through several free spectral ranges indicating less than optimum alignment at some point during the scan. If you observe this effect, the slope trim controls can be used to compensate for the differential sensitivities of the piezoelectric elements. It is very convenient to use the three bias controls to determine the relative sensitivity of the stacks before making this adjustment.

To do this, turn the SLOPE TRIM controls approximately ¼ turn clockwise. Use the ALIGNMENT controls to align the Fabry-Perot optimally for the first order in the scan. The amplitude of the subsequent orders will decrease. Observe the last order and bring it into optimum alignment with the ALIGNMENT controls. Note which control or controls are used to make this adjustment. Reset the controls to align the first order. Now adjust the SLOPE TRIM control or controls corresponding with the controls noted above such that all orders have the same amplitude. After repeating this procedure a few times all spectral orders should have approximately equal intensity indicating the PZT scan is free of tilt.

5. ALIGNMENT IN THE IR

If the substrates are not transparent to the visible, alignment is more difficult. If a laser source is available, however, alignment can be accomplished without undue difficulty.

First, by measuring the actual plate positions relative to each other, the plates should be aligned to about 0.001" to 0.002". Now, if this Fabry-Perot were to be illuminated with a large, collimated beam, and if the output could be viewed, ten or fewer straight-line fringes would be observed (at $\lambda = 10.6\mu m$). This fringe pattern can be effectively determined by illuminating the Fabry-Perot with a small laser beam, traversing the beam across the plates in X and Y, or traversing the Fabry-Perot itself, collecting the throughput with a lens and plotting the detector output. Thus the effective fringe pattern, and therefore plate alignment, can be determined. By changing the alignment and repeating the process, the Fabry-Perot alignment can be improved until the transmission is symmetric over the plates when tuned to the source wavelength.

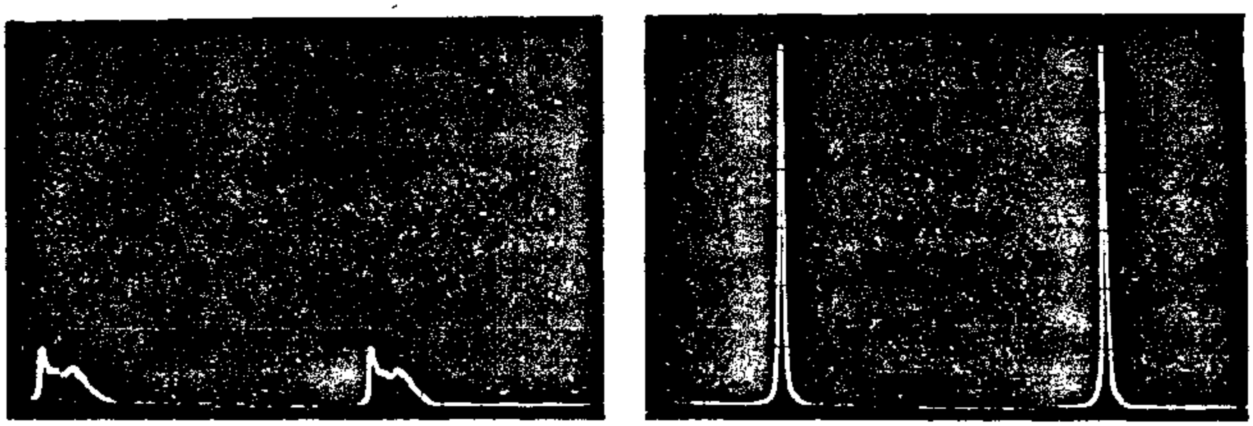
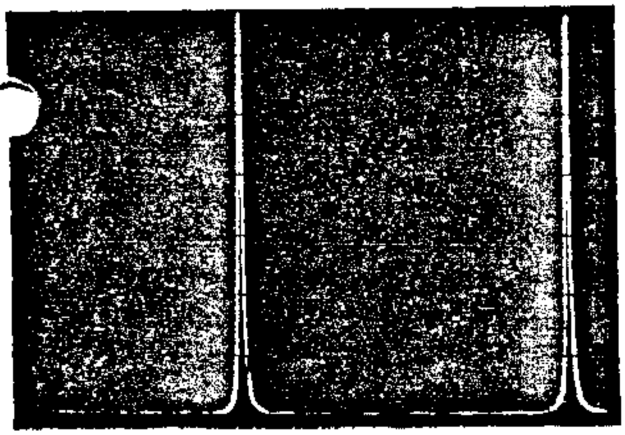
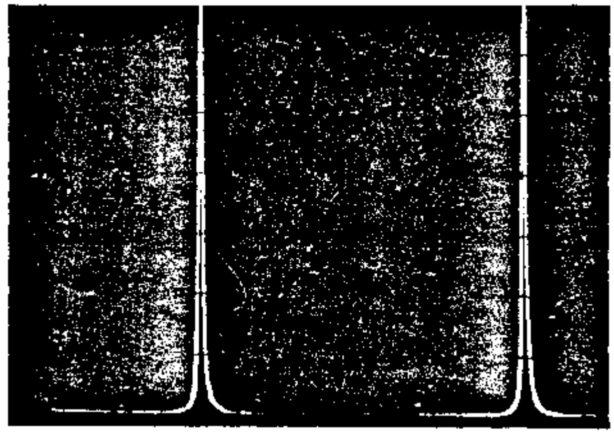


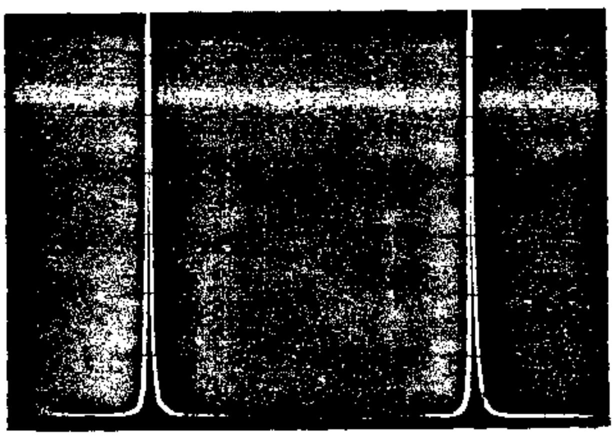
Figure 12. Fabry-Perot in Scanning Mode Showing Partial Alignment and Perfect Alignment



Pinhole to Left



Pinhole to Right



Pinhole Centered

Figure 13. Fringe Position as a Function of Pinhole Position

6. OPERATIONAL HINTS

There are, of course, methods of operating the RC-110, RC-170, RC-140 or RC-150 that you'll develop through use of the interferometers. Here are some areas that you should watch, however.

A. Operation of the interferometer in an isothermal environment will improve the performance of the interferometer. Burleigh's RC-75 Thermatrol Enclosure or RC-34 or RC-35 Thermal Box is recommended.

B. The adjustment screws are lubricated with a specially selected lubricant which provides optimum stability. Nonetheless, one should allow a period of time for the lubricant to displace from between the threads and the instrument to equilibrate after an adjustment is made.

C. If a Ramp Generator is being used, there are some points to consider:

1) The 20 and 50 millisecond ramp rate should be employed only for alignment and cursory spectral analysis.

2) The ramp waveform is rounded at the initiation and end of the ramp. The purpose is to minimize oscillation of the driving mirror from mechanical resonance effects caused by the rapid change in ramp voltage during retrace.

3) The rounding on the ramp waveform is a constant and at ramp rates longer than 20 milliseconds it is a negligible contribution to scan non-linearity.

4) For IR PZT drives it may be necessary to operate at ramp durations of 200ms to 1s to obtain optimum linearity.

D. There may be a slight "stiff" feel to the Adjustment Screws. To maintain the best stability, lubricants must be kept to a minimum and the spring loading force must be large. With a small amount of lubricant and strong springs the screw threads will feel "stiff". Better "feel" will result from a lighter spring load but stability might be reduced. An optimum compromise must be determined experimentally.

To ensure an adequate spring force for holding the screw plate against the adjustment screws, the springs should be extended approximately one-half inch or more.

E. The sapphire V-blocks that mate to the tungsten carbide ball ends of the adjustment screws are very hard and can easily be damaged by a sharp tap or allowing the adjustable plate to fall against the screws. The Fabry-Perot should therefore be handled carefully at all times.

7. TROUBLESHOOTING

A. Symptom:	No Scanning of cavity
Possible Cause:	Electronic controller not connected Electronic controller malfunction No incident electromagnetic radiation Wrong mirrors for incident radiation Detector malfunction
How to Determine Cause	Check all connections See separate electronic instruction manual Recheck coating curve Check detector operation
B. Symptom:	Severe deterioration of finesse across scan duration.
Possible Cause:	Electronic controller malfunction Poor electrical connection to one PZT stack Mechanical separation of PZT discs Separation of PZT stack assembly from invar support plates Incorrect Slope Trim setting
How to Determine Cause:	Check all connections for electrical continuity Check PZT assembly for broken or separated elements Slope Trim
C. Symptom:	Instrument doesn't hold alignment
Possible Cause:	Fractured sapphire V-blocks Clamps not tight on Super-Invar rods Dirt or other particulate matter between mirror holder and support plate Mirror holders loose in support plates Mirrors loose in holders or tab loose on mirror Broken or loose PZT stacks
How to Determine Cause:	Check all screw connections Gently press on PZT assembly at location of each stack while scanning. Fringes should return to original peak height when pressure is removed. If not, problem may be there. Remove mirror holders and clean mirror support plate. Recheck as above. Retract adjustment screws and remove springs so adjustable plate may be removed. Inspect sapphire V-blocks with magnifying glass. Small localized fractures or a major fracture can be caused by allowing the adjustable plate to "snap" into position against the adjustment screws when the springs are in place. If fractures are observed the V-blocks must be removed and replaced or removed and re-epoxied into the plate so only good surfaces are exposed. Make certain no epoxy remains on surfaces of V-blocks.

8. SPECIFICATIONS

Fabry-Perots	RC-110, RC-140, RC-170, RC-150
Type	
RC-110, RC-170	All Super-Invar construction
RC-140, RC-150	Aluminum, Super-Invar and Invar
Aperture	
RC-110, -140, -150	50mm
RC-170	70mm
Scan Method	Thermally compensated dual PZT assembly, 1.25μm scan, (6μm in IR models), 1.75μm alignment
Mirror Separation	
RC-110, -140	0-150mm
RC-150	0-10mm; 0-50mm with spacers
RC-170	0-110mm
Linearity with Burleigh Electronics	$\leqslant$ 0.1%
PZT Linearity	$\leqslant$ 1% over 1μm
Scan Hysteresis	$\leqslant$ 1% over 1μm
Adjustments	
movable mirror mount	manual sliding to set gross cavity spacing: PZT alignment to λ/500 precision, range 1.75μm
fixed mirror mount	Super-Invar screws 250μm/turn, λ/25 alignment sensitivity with 2" delrin knobs
Read Outs	
cavity spacing	Scale and vernier reads to .1mm: 0.02mm if calibrated
screws	dials read to 5μm
Finesse	depends on mirrors
Performance	see performance section

Fabry-Perot Mirrors	RC-600 Series, RC-800 Series
Material	
RC-600 Series	Fused Silica
RC-800 Series	ZnSe
Flatness @ λ = 550nm	
surface 1	λ/100 or λ/200
surface 2	λ/10
Holder	Invar
Coating	high reflectance, multi-layer dielectric on surface 1; AR on surface 2
Wedge	
RC-600 Series	$\geq$ 10′
RC-800 Series	$\geq$ 3′

Collimator	RC-41
Construction	Aluminum
Length	275mm nominal
Pinholes	50, 100, 200, 500μm
Adjustments	orthogonal micrometer adjust of pinhole location
Lens Focal Length	254mm (visible models only)
Mounting	Three 10-32 clearance holes located on a 4.5" dia. bolt circle. Affixes to RC-41-1 mounting brackets. RC-41-1 affixes collimator to work bench with four ¼-20 screws on a 4" square hole pattern

Multipass Option	RC-22, RC-27
Type	Coupled corner cubes
Aperture	
RC-22, 3 pass	11mm
RC-22, 5 pass	6mm
RC-27, 3 pass	15mm
RC-27, 5 pass	9mm
X-Y adjustment	± 1/16"
Corner cube quality	5-10 sec.
Entrant surface coating	Multi-layer AR for R $\leq$ 0.5%
Housing and masks	Black anodized aluminum

Mounting Bases	RC-24
Type	Composite, kinematic
Vertical adjust	1.5cm
Elevation adjust	3°
Azimuth adjust	3°
Length standard	Super-Invar

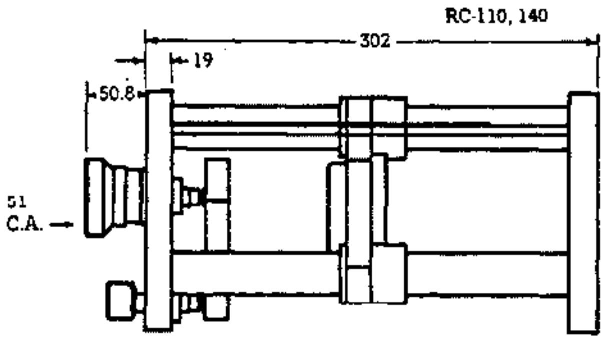
Thermal Box	RC-34
Size	19" x 10" x 10½"
Insulation	½" polyurethane, Super-Insulation
Construction	½" stained birch

Thermatrol[tm] Enclosure	RC-75
Size	19" x 10" x 10½"
Insulation	½" to 1" polyurethane, alumized Mylar "Super-Insulation"
Construction	½" stained birch
Temperature Stability	$\leq$ 0.05°C
Ambient Range	22° ± 3°C

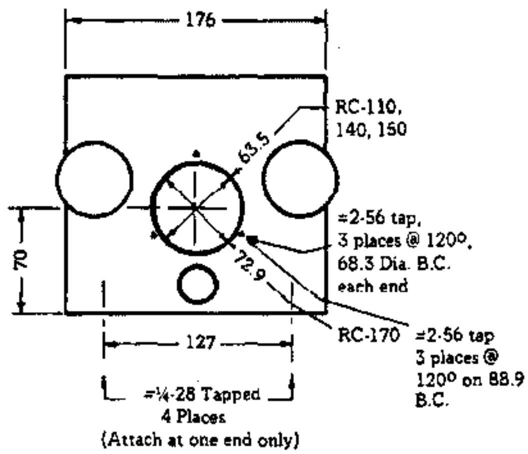
9. WARRANTY

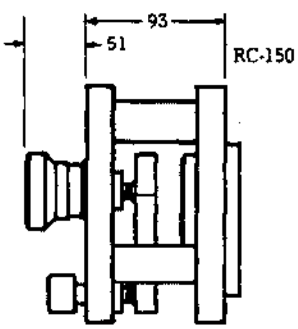
Burleigh Fabry-Perots are warranted against defects in material and workmanship for a period of one year after date of delivery and the return of Burleigh's warranty card. During the warranty period, Burleigh will repair or at its option, replace parts which prove to be defective when the instrument is returned prepaid to Burleigh Instruments, Inc. Before return of an instrument always call Burleigh for approval of the return. The warranty will not apply if the insturment has been damaged by accident, misuse, or as a result of modification by persons other than Burleigh personnel.

10. OUTLINE DIMENSIONS



All dimensions in mm





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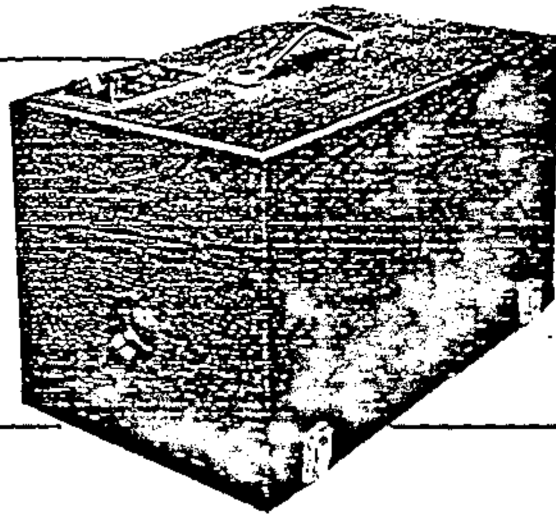


Fabry-Perot Options Instruction Manual

1. Thermatrol
2. Thermal Box
3. Mounting Base
4. Collimators

CONTENTS PAGE

1. GENERAL

A. Introduction

This Instruction Manual describes several popular options for Burleigh's RC Series Fabry-Perot Interferometer. They have been included in one manual since most customers order two or more of these items with their Fabry-Perot system.

The RC-75 and RC-77 Thermatrol Enclosures and RC-34 and RC-37 Thermal Boxes are used to house the entire Fabry-Perot. They insulate the systems and keep the precision optics dust free.

The RC-24 Mounting Base, which can be mounted inside the thermal enclosures, allows for positioning of the entire Fabry-Perot and includes a Super-Invar reference plane as well as kinematic support.

The RC-41 and RC-47 Collimators are used at the output of the Fabry-Perot to collect the transmitted light. A series of interchangeable pinholes control the angular extent of the interfering rays.

B. Unpacking

All Burleigh instruments are shipped in heavy duty cartons which protect the unit during normal handling and transportation. If the outside of the shipping carton is damaged, notify your shipping department immediately. The shipping department may wish to notify the carrier at this point.

If the shipping carton is undamaged, the instrument should be removed from the carton. If damage is evident visually, notify your shipping department and Burleigh Instruments, Inc., immediately.

C. Warranty

Burleigh products are warranted against defects in material and workmanship for a period of one year after date of delivery with the return of Burleigh's warranty card. During the warranty period, Burleigh will repair or at its option, replace parts which prove to be defective when the instrument is returned prepaid to Burleigh Instruments, Inc. Before return of an instrument always call Burleigh for approval of the return. The warranty will not apply if the instrument has been damaged by accident, misuse, or as a result of modification by persons other than Burleigh personnel.

2. RC-75/RC-77 THERMATROL™ TEMPERATURE CONTROLLED ENCLOSURES

A. Instrument Description

In the following description the RC-75 will be used in all examples. All statements, however, also apply to the RC-77 Thermatrol enclosure for Burleigh's 70mm Fabry-Perot System.

The RC-75 provides a well insulated, dust free enclosure for Burleigh Fabry-Perots and can be used to control the temperature of the Fabry-Perot to ± 0.1°C. The shell is constructed of 11mm thick walnut stained birch. The control panel, located on the top of the box, consists of two toggle switches, three LED's and a 1 amp slow blow fuse. See Figure 1. The sensing and control circuitry as well as the power supply is located inside under the control panel. The interior is lined with 19mm thick urethane for excellent thermal isolation. Heater elements are bonded to metal radiating plates which are then attached to the insulated inner walls.

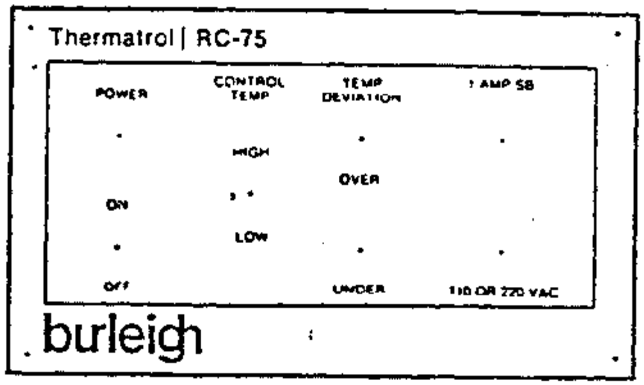


Figure 1

The upper portion of the RC-75 is removed from the base by releasing the four steel dip-latches. A cutout for feeding through the electrical connection to the Fabry-Perot is provided on the bottom side of the upper section. Anti-reflection coated utility windows are also supplied with each instrument. The standard 50.8mm (76.2mm in the RC-77) diameter windows are AR coated for the visible. These windows are easily removed should the user desire to change or replace them.

The base of the RC-75 is large enough for an RC-24 Composite Kinematic Mounting Base which permits several degrees of θ,ϕ and α adjustment, as well as approximately 12.7mm of vertical adjust. These adjustments are useful for properly aligning the entire Fabry-Perot with respect to the incoming radiation. The RC-24 is normally mounted in the RC-75 at the factory although it can be done in the field with little difficulty.

The RC-75 can actively control the temperature of a Fabry-Perot to an accuracy of ± 0.1°C for a 6°C room temperature change.

The probe assembly found inside the box is to be attached to the Fabry-Perot by way of the magnets on its side. The best location is the side of the adjustable mirror plate. It is advantageous to apply a small amount of thermal grease to the probe to aid heat transfer.

The operating temperature is preset to approximately 29°C or 33°C (depending on switch setting) and will bring the Fabry-Perot to this temperature in approximately one to two hours.

B. How It Works

The temperature is sensed with a thermistor in a precision bridge network. The bridge signal is then amplified and compared to a stable reference ramp generated in the control circuitry. The zero voltage switch takes this information and through a triac, proportions the amount of power supplied to the heaters for regulation of the temperature.

C. How To Use The Thermatrol Enclosures

Place the magnetic thermistor probe on the device to be controlled. On Burleigh model Fabry-Perots, the best position for the probe is on the side of the adjustable mirror plate. On other instruments it is best to experimentally determine the optimal sensing point. The device to be controlled is then placed on the wooden base and the upper portion of the RC-75 is latched into place. Make sure any direct electrical connections to the Fabry-Perot are fed through the cutout. A tight seal is very important for proper operation. The latches line up with the top for one orientation only to avoid tedious system realignment every time the top is removed. Check the RC-75 for correct operating voltage which will be either 110vac or 220vac. Each RC-75 is wired for one of the above voltages and should the user desire to rewire for a different line voltage, consult Burleigh for details. Plug in the line cord. Turn the power switch to the ON position. A LED immediately above the power switch should light indicating that AC power is present. Consult the troubleshooting section should the unit fail to operate in this manner.

There are two temperature set points, labeled high and low, which are selected with the control temperature switch. These two ranges are provided so the user can optimize operation for his own particular laboratory environment. The standard operating temperatures are 33°C and 29°C (for high and low respectively). Other set points are available. The user should consult the factory for further details.

Two temperature deviation LED's give an indication of the sensor temperature relative to the set point chosen with the control temperature switch. The upper LED lights when the temperature is 0.1°C higher than the set point and the lower one comes on when the temperature is 0.1°C lower than the set point. Both will remain off when the temperature controller is operating to within ± 0.1°C of the set point. Depending on the mass of the object in the box, the set point selected and the laboratory conditions, it generally takes one to two hours to achieve equilibrium, but under some conditions as much as four hours.

Note: if the laboratory environment is well controlled and free of drafts, superior Fabry-Perot performance may be obtained by not using the temperature control feature of the RC-75. It should always be determined which mode of operation is best for your laboratory conditions.

D. Troubleshooting - Test Points

The reference point for all voltages is AC neutral. To observe waveforms on an oscilloscope the scope line cord <u>must be</u> isolated from earth ground. (A three prong to two prong adapter serves the purpose). The oscilloscope's ground can now be connected to AC neutral (at minus side of C4) and the pertinent waveforms observed. It is suggested that a multimeter be used in place of the oscilloscope for the voltage measurements. Note. This unit uses a 1 amp slow blow fuse on the front panel. Do not use any other type of fuse.

1) With line cord unplugged check operation of thermistor. Resistance at J1-9 and J1-11 should be approximately 2.2KΩ at 25°C.

2) With power on, supplies at positive side of C4 and pin 4 of U1 (LM324) should both read 6.8 ± 0.5VDC.

3) Output at pin 7 of U1 (LM324) should swing from ground to 5 volts as probe is heated and cooled (heating can be by holding probe in hand).

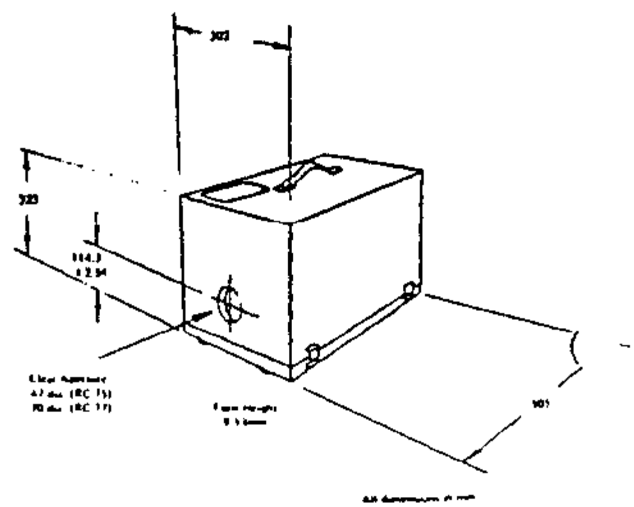
4) Reference ramp at positive side of C5 should run from 1.5 volts to 4 volts DC in an 8 to 10 sec. interval.

If any of the test points indicated above are different than described, contact Burleigh for further troubleshooting and repair suggestions.

E. Specifications

Power:	Thermatrol enclosures are wired at the factory for either 110 or 220 VAC operation. To change the line voltage consult the factory.
Fuse:	1 amp Slow Blow
Temperature Control:	± 0.1°C for a 6°C room temperature change
Standard Set Points:	29°C and 33°C
Outer Dimensions:	505mm L x 302mm W x 323mm H
Inner Dimensions (including urethane):	416mm L x 223mm W x 238mm H
Clear Aperture:	
RC-75	47mm
RC-77	70mm
Optical Axis Height:	114.3 ± 2mm
Height of feet:	9.52mm

F. Outline Dimensions



3. RC-34/RC-37 THERMAL BOXES

A. Instrument Description

In the following description the RC-34 will be used in all examples. All statements, however, also apply to the RC-37 Thermal Box for Burleigh's 70mm Fabry-Perot System.

RC-34 Thermal Box is identical to the RC-75 Thermatrol except that it does not include active temperature control. The construction is of 11mm birch lined with 19mm urethane insulation. Removable windows, AR coated for the visible, seal the interior of the RC-34 from drafts.

The RC-34 provides a well insulated, dust-free enclosure for Burleigh Fabry-Perots. It protects the instrument from the effects of drafts or rapid temperature changes. The RC-24 Composite Kinematic Mounting Base can be attached inside the RC-34 on the base section for θ, ϕ, α and vertical adjustment of the Fabry-Perot. It is recommended that the RC-24 be attached to the RC-34 at the factory, but it can be fitted in the field with little difficulty.

The dimensions of the RC-34 are identical to the RC-75. Consult the appropriate paragraphs of the RC-75 section of this manual for tips on setting up the RC-34.

4. RC-24 COMPOSITE KINEMATIC MOUNTING BASE

A. Instrument Description

The RC-24 is designed to provide three functions. First, it provides three degrees of angular adjustment of the Fabry-Perot about three perpendicular rotation axes (θ, ϕ and α) as well as approximately 12.7mm of vertical adjustment. These adjustments are necessary to properly align the axis of the Fabry-Perot with respect to the optical axis of the system.

Second, it provides a Super-Invar stabilized mounting reference for the Fabry-Perot. This insures that the end plates of the Fabry-Perot are not stressed by forces exerted by thermally induced length changes in the Fabry-Perot support. The Super-Invar length standard is itself mounted such that it cannot be affected by the aluminum top plate of the RC-24.

Third, the RC-24 provides a three point kinematic support for the Fabry-Perot to allow removal and precise repositioning of the Fabry-Perot. This feature can be very useful when aligning a complex optical system. The three point mounting also insures that the Fabry-Perot cannot be warped or stressed.

B. How To Use The RC-24

1. Attaching the RC-24

The RC-24 is secured to the base of the RC-75 or RC-34 or to an optical bench with four ¼-20 screws in the bottom plate of the RC-24. The top plate is removed by carefully detaching the spring and lifting. The holes in the bottom plate can be used as a template. If the RC-24 is being attached to an existing RC-34 or RC-75 the urethane in the base of these enclosures must be carefully cut to exactly fit the RC-24.

2. Mounting the Fabry-Perot on the RC-24

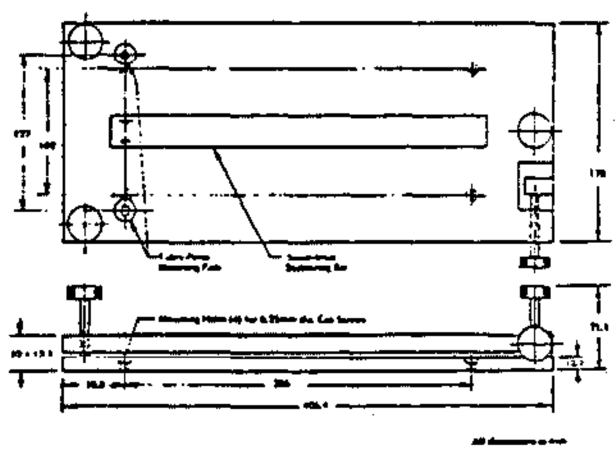
The Fabry-Perot should rest on the RC-24, secured only by its own weight. Two special ball end stainless screws, provided with the RC-24, should be screwed into the holes in the bottom of the front end plate of the Fabry-Perot until they seat. Then the Fabry-Perot is placed so that these ball end screws seat in the bore and slot in the top of the RC-24, with the rear end plate resting on the Super-Invar reference strip.

CAUTION: Always remove the Fabry-Perot from the RC-24 Mounting Base before transporting the system. Unless great care is taken not to tilt the assembly, the Fabry-Perot can slip loose and be damaged.

C. Specifications

Vertical adjustment	> 12.7mm
θ tilt (about horizontal axis ⊥ optic axis)	> 3°
ϕ tilt (about vertical axis ⊥ optic axis)	> 5°
α tilt (about horizontal axis ∥ optic axis)	> 5°

D. Outline Dimensions



5. RC-41/RC-47 COLLIMATORS

A. Instrument Description

Burleigh's RC-41 and RC-47 Collimators are normally used as light collectors with RC Series Fabry-Perot Interferometers. A large diameter, long focal length (about 250mm F.L.) achromatic doublet is focused onto a pinhole, thus controlling the angular extent of radiation passing through the Fabry-Perot which is incident on the detector. Refer to the Fabry-Perot Tech Memo for further detail on the optical system.

It is also recommended in high contrast systems that a collimator be used at the input side. This will serve to eliminate radiation with an unacceptable angular extent, thus reducing the possibility of unwanted stray light and scatter.

The aperture of the collimator is matched to the usable aperture of the Fabry-Perot optics. The RC-41, used with 50mm optics, has a 48mm aperture. The RC-47 for 70mm optics, has a 68mm aperture. The doublet can be precisely focused onto the plane of the pinhole. A visible eyelens is included to simplify this adjustment.

A series of precision pinholes (50, 100, 200 and 500μm) are mounted and centered in removable holders, so that the proper diameter can be selected depending on the system. A micrometer driven X-Y stage is used to position the pinhole.

Both collimators are available with optics for the infrared or UV - as designated by the suffixes "-IR" or "-UV". Initial focus and adjustment may require more effort, as is normally the case in non-visible systems, and the visible eyelens may not be usable.

The RC-41-1 Collimator Mounting Bracket is recommended. This bracket will simplify free-standing mounting of the Collimator, which has a cylindrical body.

B. Adjustment of the Collimator

The focus of the collimator lens must first be adjusted. This is accomplished before the collimator is attached to its base. Screw the pinhole device containing the eyepiece lens into the X-Y slide. Note that this device contains a rather large hole approximately 3mm in diameter in lieu of an actual pinhole. Adjust the eyepiece lens until the edge of this hole is seen clearly in sharp focus. The edge of the hole is in exactly the same position along the axis of the objective lens as that of the actual pinholes. Now look at a very distant object through an open window, and adjust the collimator objective lens until the image of the distant object seems to be suspended in space at the plane of the hole. Focusing is now complete, and the collimator may be attached to its base.

With the Fabry-Perot illuminated as in Figure 2, view the ring pattern through the eyepiece lens of the collimator. Adjust the lateral position of the eyepiece with the two micrometer screws, such that the ring pattern is exactly concentric with the large hole. The eyepiece may now be unscrewed and replaced with the working pinhole. The pinholes have been accurately machined so that they will be close to the exact center of the large hole on the X-Y slide. Thus, the working pinhole will now be within about 25μm of the correct position.

USE CAUTION WHEN VIEWING THE BEAM TO AVOID EYE DAMAGE; THE INTENSITY OF THE BEAM SHOULD BE ATTENUATED AS MUCH AS POSSIBLE.

C. Specifications

Construction	Aluminum
Length	280mm nominal
Pinholes	50, 100, 200, 500μm
Adjustments	Orthogonal micrometer adjust of pinhole location
Aperture	48mm (RC-41, RC-41IR, RC-41UV) 68mm (RC-47, RC-47IR, RC-47UV)
Lens Focal Length	254mm (visible models only)
Mounting	Three 10-32 clearance holes located on a 4.5" dia. bolt circle. Affixes to RC-41-1 mounting brackets. RC-41-1 affixes collimator to work bench with four ¼-20 screws on a 4" square hole pattern

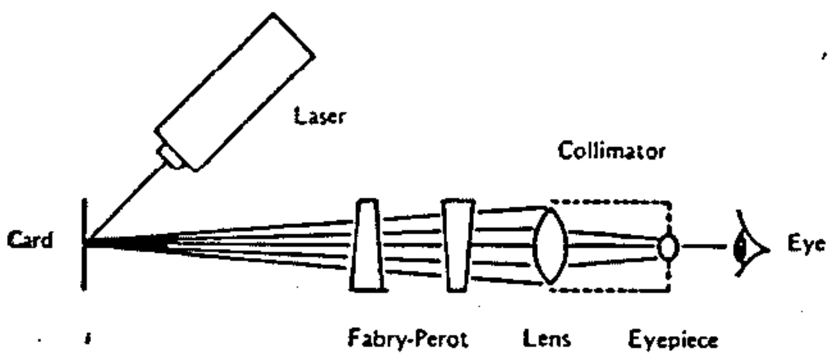
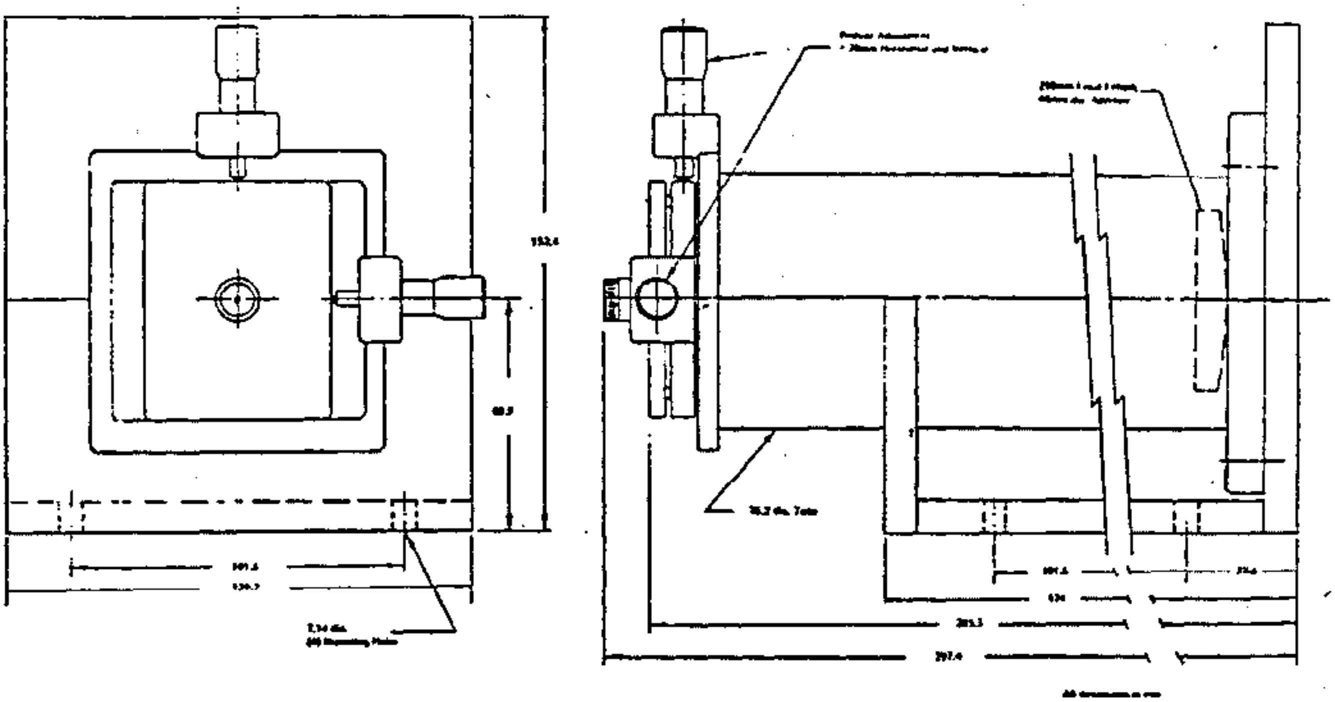


Figure 2

Viewing Fabry-Perot Circular Fringes through Collimator

D. Outline Dimensions



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